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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Virtually all of the important research results obtained during execution of the referenced grant were reported in journal articles and conference papers. Brief summaries of the major contributions are given. The summaries relate to ...

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DIGITAL SIGNAL PROCESSING

Final Report
Period: 1 Feb. 1979 - 31 March 1982

Authors: J.B. Thomas, Professor
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Date: June 7, 1982

U.S. Army Research Office - Durham

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1. Summary of Research Accomplishments

Virtually all of the important research results obtained during execution of the referenced grant were reported in journal articles and conference papers, and these are listed in Section 3. We give here brief summaries of the major contributions; reference numbers are to Section 3.

A. Digital Filter Design [1,2,6,9,11,12,13,14,17,23,25]

References [1,9,17] all deal with the application of linear programming and the simplex algorithm to the design of FIR digital filters. This approach allows more general constraints to be put on the frequency response specification than does the Remez exchange method. In [1] Hilbert transform filters are designed with a concavity constraint on the magnitude frequency response. In [9,17] it is shown how the problem of designing near-allpass FIR filters with prescribed phase can be formulated and solved as a linear program. A computer program is given in [17], together with examples of design results for full-band chirp filters.

In [12,23] a new method is given for varying the parameters of an IIR filter so as to change its frequency response. The method is fast and numerically stable.

References [2,6,11,13,14,25] all deal with the problem of choosing finite word-length coefficients for digital filters. Item [6] is a program for designing finite word-length IIR digital filters, and appears in an IEEE Sponsored book which is a collection of software for digital signal processing. Item [4] deals with the tradeoff between filter-length and word-length in FIR filters. It is proved that these is a lower bound on the approximation error for linear phase FIR filters when the coefficients are constrained to be b-bit numbers, no matter how high an order filter is used. An explicit and easily-computed bound is developed in [11,25]. This bound is useful for estimating the coefficient word-length necessary for a given FIR application. Items [2,13] deal with the problem of actually designing FIR filers with given word-length: the results of a fast, heuristic method are compared with a much slower but optimal method. The results show that the heuristic is often quite effective on this difficult problem.

B. Theory of the DFT [10,15,34]

These papers deal mainly with the eigenstructure of the Discrete Fourier Transform. While the multiplicities of the eigenvalues of the DFT are well known, there is as yet no simple characterization of an orthonormal basis for this fundamental transformation. A new method is given for computing such an orthonormal set of eigenvectors. It is also shown how fractional powers of the DFT can be efficiently computed, and this suggests applications to multiplexing and transform coding that will be investigated in the future.

C. New Algorithms (39,40]

Reference [39] gives an algorithm (and a complete program) for factoring very high degree polynomials. The emphasis is not on ill-conditioned cases, but rather on the numerical problems associated with high degree. Polynomials of degree 511 are routinely factored with this method. The immediate applications are to phase unwrapping and the determination of the minimum-phase version of a signal.

Reference [40] represents work in a new applications area; linear programming is used to formulate the problem of recognizing a noisy version of a given template. This uses previous experience with linear programming for filter design, in a new two-dimensional signal processing application.

D. Communication Networks [3,32,33,35,38]

This group of papers deals with various complexity issues that arise in communication and computer network design. Item [33] is a general summary of the area (with a review of computational complexity theory), and was presented at a NATO advanced study institute. Items [3,35] treat the problem of deadlock avoidance in packet switching networks; several basic problems are shown to be NP-complete. Item [38] deals with the problem of efficient address assignment in (mobile) packet radio networks. Item [32] shows that a very simple version of the problem of locating concentrators is NP-complete.

E. VLSI Architectures for Signal Processing [24,31]

This is work along new lines, work that is being pursued under the continuation of this grant. Reference [24] shows that some special-purpose processor design problems are NP-complete (and therefore very likely intractable). Item [31] describes some structures for convolution and filtering which are well-suited for VLSI layout, and which achieve a very high degree of pipelining. Present work is focused on the asymptotic time, area, and energy requirements of highly - pipelined structures, and on their efficient geometric layout.

F. Adaptive and Nearly Optimal Detectors [5,8,22,29]

In [5] and [8,22], nearly optimal detectors are found for non-Gaussian noise and for correlated Gaussian noise. In both cases, the detector structure is constrained to possessing a very short memory, resulting in a simple and easily implemented structure. In [22], the computational aspects of filter realization are emphasized. In [29], measures of the tail behavior of non-Gaussian noise are explored with the goal of implementing nearly optimal adaptive detectors. Two specific tail measures are shown to possess desirable and useful properties.

G. Robust Detection [16,27]

In [16], we extend the notion of the robust detection of known signals to the stochastic signal case. The proposed detectors are shown to be robust over a class of noise statistics, based on the Huber-Tukey mixture model, which contains noises characterized by heavy-tailed density functions. In [27], we investigate the Pearson family as models for nearly Gaussian noise in the framework of robust detection.

H. Structure of Random Processes [4,7,19,21,30,36,37]

In [4,7,21,30, and 36], we are concerned with the dependency structure in non-Gaussian random processes. In these papers, various statistical representations of this dependency are proposed and studied for the insight they give into the design of optimal signal detectors operating in such noise. In [37], we consider a large class of non-Gaussian noises and derive the optimal detectors for signals in such noise. We compare the (complicated) optimal detectors to suboptimal schemes and show that, in some cases, substantially simpler detectors operate almost optimally. In [19], we find optimal memoryless detectors operating in a dependent noise environment. Such detectors are substantially simpler than detectors with memory and are easier to incorporate into an adaptive system.

I. Quantization [26]

In [26], we study quantization schemes which are nearly optimal but require only an incomplete statistical knowledge of the processes to be quantized. In typical non-Gaussian noise environments, much less than a complete statistical description if the noise is usually all that is available.

J. Sequential Detection [18,20,28]

In [18] and [20], we propose a modified sequential detector which is much simpler than conventional sequential detectors but retains most of the efficiency of such devices. In [20], we show that carrier phase error exhibits a threshold effect which is of considerable practical importance in sequential data transmission.

2. Participating Personnel

2.A. Faculty Supported in Part by this Grant:

J.B. Thomas (co-principal investigator)
K. Steiglitz (co-principal investigator)

2.B. Graduate Students Supported or Partially Supported by this Grant:

M. Buchinsky	A. Martinez
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2.C. Participating Graduate Students Supported by Departmental or Other Means:

J. Abrahams	H.V. Poor
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Y.F. Huang	M.D. Wood
C.C. Lee	Y.C. Jenq
M. Mami	

2.D. Ph.D. Disserations Completed:

W. P. Niedringhaus, "Approximation of Reals by Rationals, with Applications to Various Optimization Problems," April 1980.

C. C. Lee, "On Nonparametric, Sequential, and Mixed-Sample-Size Signal Detection Procedures," July 1980.

A. Mirzaian, "Topological Optimization of Computer Communication Networks: Approximate Algorithms and Bounds," October 1981.

E. Modugno, "The Detection of Signals in Impulsive Noise," February 1982.

P. Cappello, "VLSI Architectures for Signal Processing," (tentative title), expected August 1982.

3. Publications (jounral articles and conference papers including spillover from previous contract)

1. K. Steiglitz, "Optimal Design of Digital Hilbert Transformers with a Concavity Constraint," Proc. 1979 Int. Conf. Acoustics, Speech, and Signal Processing, pp. 824-827, Washington, D.C., April 2-4, 1979.

2. D. Kodek and K. Steiglitz, "Comparison on Optimal and Local Search Methods for Designing Finite Word-Length Digital Filters," Proc. 1979 Conf. on Information Sciences and Systems, pp. 1-4, Johns Hopkins University, Baltimore, Md., March 28-30, 1979.

3. S. Toueg and K. Steiglitz, "Some Complexity Results in the Design of Packet Switching Networks," Proc. 1979 Conf. on Information Sciences and Systems, pp. 146-154, Johns Hopkins University, Baltimore, Md., March 28-30, 1979.

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